BROOKHAVEN
NATIONAL LABORATORY

NSRL-5 RUN

FINAL REPORT

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BNL/NASA webpage:
http://www.bnl.gov/medical/NASA/NASA-home%20frame.htm

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EXECUTIVE SUMMARY

During the spring of 2005, a series of radiobiological and physics experiments were performed using the NASA Space Radiation Laboratory to accelerate heavy ion beams (NSRL-5). These experiments were part of the fifth NSRL scientific run sponsored by NASA's Space Radiation Health Program (SRHP) heavy ion radiobiology research program at BNL.

A total of 42 proposals were reviewed by the BNL' SACR to participate in the NSRL-5 run. Thirty eight proposals participated in the actual run. Twenty four institutions from the United States were represented, totaling 123 users. More than 2000 biological samples were exposed at the NSRL beam line, employing 372 hours of beam time (36.5 hours for in vivo studies, 135 hours for in vitro studies and 48 hours for physics experiments) delivered in a six-weeks period. In addition, 20 hours were used for beam development and, 94.5 hours for set-up and dosimetry. A total of 14 hours of beam time were lost due to accelerator related problems.

During NSRL-5, Booster provided iron (300, 600 and 1000 MeV/nucleon), protons (1 GeV/n), sequential fields of iron and protons (1 GeV/n), oxygen (600 and 1000 MeV/nucleon), silicon (300 and 600 MeV/nucleon) and carbon (290 MeV/nucleon) beams for biology and physics experiments. The dose/rates used were as low as 0.1 cGy/min and as high as 600 cGy/min. The general spill rate employed was 20 with a duration of 300 msec/spill. The spill fluence range was (particles/spill) from 1.4×10^7 (max) and 200 (min). Square beam spots as big as 20 x 20 cm and small as 1 x 1 cm was employed for biology and physics experiments. Tandem-Booster-NSRL complex delivered a sequential field composed by iron and protons with energies of 1 GeV/n with a steady and repeatable switching from protons to iron. The longest switching time was 60 minutes and the shortest was 2 minute. The typical one was ~2 minutes.

Tandem-Booster set-up started on June 6 with the transport and circulation of p beams at the NSRL complex. Beam was tuned into cave on March 27. 1000 MeV/n p beams were available for tuning on March 28. Biology studies started on the morning of March 29 using Fe beams (Chen, NASA). NSRL-5 officially ended at 1930 pm, May 5, 2005.

NSRL-5 Projects Reviewed by the BNL's Scientific Advisory Committee in Radiobiology:

Proposal	PI	Sponsor	Status	Participation
B-3	Cucinotta/Wu	NASA	Renewal	Yes
B-7	Rabin	NASA	Renewal	Yes
B-10	Chang	NSBRI	Renewal	Yes
B-52	Gewirtz	NSBRI	Renewal	Yes
N-65	Vazquez	NSBRI	Renewal	Yes
B-67	Blakely	NASA	Renewal	Yes
B-73	Sutherland	DOE/NASA	Renewal	Yes
B-74	Chatterjee	NASA	Renewal	Yes
B-75	Ford	DOE/NASA	Renewal	Yes
B-76	Green	DOE/NASA	Renewal	Yes
N-80	Gonda	NASA	Renewal	No
N-86	Wang	NASA	Renewal	Yes
N-88	Sutherland	NASA	Renewal	Yes
N-89	Held	NASA	Renewal	Yes
N-90	Bailey	NASA	Renewal	Yes
N-91	Rydberg	NASA	Renewal	Yes
N-96	Nelson	NASA	Renewal	Yes
N-97	Kronenberg	NASA	Renewal	Yes
N-99	Zhao	NASA	Renewal	Yes
N-102	Hall	NASA	Renewal	Yes
N-103	Barcellos-Hoff	NASA	Renewal	Yes
N-104	Weil/Ulrich	NASA	Renewal	Yes
N-106	Gatley	NASA	Renewal	Yes
N-107	Kennedy	NASA/NSBRI	Renewal	Yes
N-110	Nelson	NASA	Renewal	Yes
N-112	Obenaus	NASA	Renewal	Yes
N-116	Benton	NASA	Renewal	Yes
N-123	Radeka	NSBRI	Renewal	Yes
N-129	Limoli	NASA	New	Yes
N-130	Ware	NASA	New	Yes
N-131	Kohwi-Shigematsu	DOE/NASA	New	Yes
N-132	Amundson	NASA	New	Yes
N-133	Azzam	PB	New	Yes
N-134	Chen	NASA	New	Yes
N-135	Pluth	NASA	New	Yes
N-136	Britt	NASA	New	Yes
N-137	Wilkins	NASA	New	No
N-138	Behavresh	NASA	New	No
N-139	Krucker	NASA	New	Yes
N-140	Saganti	NASA	New	Yes
N-141	Krucker	NASA	New	Yes
N-142	Burns	NASA	New	No

NSRL-5 PARTICIPANTS

Exp.	Participants	Affiliation	Title
B-3	**F. Cucinotta***	NASA , Johnson Space Center	Ph.D., Principal Invest.
	H. Wu	"	Ph.D., Co-Worker
	K. George	"	M.S., Co-Worker
	L. Ren	"	Ph.D., Co-Worker
	M. Hada	"	PhD., Co-Worker
B-7	**B. Rabin**	UMBC, Baltimore, MD	Ph.D, Principal Invest.
	J. Joseph	HNRCA, USDA-ARS, Boston, MA	Ph.D., Co-Worker
	A.Carey	"	Ph.D., Co-Worker
	K. Carrahill	UMBC, Baltimore, MD	B.S., Co-Worker
	B. Maloney	"	B.S., Co-Worker
B-10	**P. Chang**	SRI International, CA	Ph.D, Principal Invest.
	J. Bakke	"	B.S., Co-Worker
	A. Puey	"	B.S., Co-Worker
B-52	**B. Sutherland**	BNL, Upton, NY	Ph.D, Principal Invest.
	A. Gewirtz	University of Pennsylvania	Ph.D., Co-Principal Invest.
	P. Bennett	BNL, Upton, NY	M.S., Co-Worker
	M. Naidu	"	Ph.D., Co-Worker
	D. Roy	"	Ph.D., Co-Worker
	M. Hada	"	Ph.D., Co-Worker
	G. Zhou	"	Ph.D., Co-Worker
	J. Sutherland	"	Ph.D., Co-Worker
	D. Monteleone	"	B.S., Co-Worker
	J. Trunk	"	B.S., Co-Worker
	G. Gangenahalli	University of Pennsylvania	B.S., Co-Worker
	J. Millholland	"	B.S., Co-Worker
B-65	**M. Vazquez**	BNL, Upton, N.Y.	MD, PhD., Principal Invest.
	P. Guida	"	Ph.D., Co-Worker
	A. Billups	"	B.A., Co-Worker
	B. Pyatt	"	M.S., Co-Worker
	L. Thompson	"	B.S., Co-Worker
	A. Kim	"	B.S., Co-Worker
B-67	**E. Blakely**	LBNL, Berkeley, CA	Ph.D, Principal Invest.
	P. Chang	SRI International, Menlo Park, CA	Ph.D., Co-Worker
	J. Bakke	SRI International, Menlo Park, CA	B.S., Co-Worker
	C. Rosen	SRI International, Menlo Park, CA	B.S., Co-Worker
	K. Bjornstad	LBNL, Berkeley, CA	B.S., Co-Worker
B-73	**B. Sutherland**	BNL, Biology Dept., Upton, NY	Ph.D, Principal Invest.
	P. Bennett	"	M.S., Co-Worker
	M. Naidu	"	Ph.D., Co-Worker
	D. Roy	"	Ph.D., Co-Worker
	M. Hada	"	Ph.D., Co-Worker
	G. Zhou	"	Ph.D., Co-Worker
	J. Sutherland	"	Ph.D., Co-Worker
	S. Tafrov	"	Ph.D., Co-Worker
	D. Monteleone	"	B.S., Co-Worker
	J. Trunk	"	B.S., Co-Worker
B-74	**A. Chatterjee***	LBNL, Berkeley, CA	Ph.D., Principal Invest.
	P. Wilson	Colorado State University, Fort Collins, TX	B.S., B.A., Co-Worker
B-75	**J. Ford**	Texas A&M Univeristy,College Station, TX	Ph.D., Principal Invest.
	L. Braby	"	Ph.D., Co-Worker
	A. Maslowski	"	PhD., Co-Worker
B-76	**L. Green**	Loma Linda University, CA	Ph.D, Principal Investigator
	B. Bianski	"	Ph.D., Co-Worker

Exp.	Participants	Affiliation	Title
N-86	**Y. Wang**	Thomas Jefferson University, PA	Ph.D, Principal Investigator
	H. Wang	"	Ph.D, Co-Worker
	R. Liu	"	Ph.D, Co-Worker
	X. Wang	"	Ph.D., Co-Worker
N-88	**B. Sutherland**	BNL, Upton, NY	Ph.D., Principal Invest.
N-89	**K. Held**	Massachusetts Gen. Hosp./Harvard M. School	Ph.D., Principal Invest.
	H. Yang	"	Ph.D., Co-Worker
	V. Anzenberg	Massachusetts General Hospital	B.S., Co-Worker
	K. Mahase	Massachusetts General Hospital/MIT	B.S., Co-Worker
N-90	**S. Bailey**	Colorado State University, Fort Collins, CO	Ph.D., Principal Invest.
N-91	**B.Rydberg**	LBNL, Berkeley, CA	Ph.D, Principal Invest.
	T. Groesser	"	M.S., Co-Worker
	B. Cooper	"	Ph.D., Co-Worker
N-96	**G. Nelson ***	Loma Linda University	Ph.D., Principal Investigator
	T. Jones	"	B.S., Co-Worker
	A. Smith	"	B.S., Co-Worker
	S. Rightnar	"	B.S., Co-Worker
	C. Perez	"	B.S., Co-Worker
N-97	**A. Kronenberg**	LBNL, Berkeley, CA	Sc.D., Principal Invest.
	S. Gauny	"	M.S., Co-Worker
	L. Connolly	Oregon Health & Science University	B.S., Co-Principal Invest.
	M. Turker	"	Ph.D., Co-Worker
	H. Sudo	LBNL, Berkeley, CA	Ph.D., Co-Worker
	E. Kwoh	"	B.S., Co-Worker
N-99	**Y. Zhao**	Columbia University	Ph.D, Principal Invest.
	C. Piao	"	Ph.D., Co-Worker
N-102	**E. Hall***	Columbia University	Ph.D, Principal Invest.
	L. Smilenov	"	Ph.D., Co-Worker
	R. Baker	"	Sr., Tech., Co-Worker
N-103	**M. Barcellos-Hoff**	LBNL, Berkeley, CA	Ph.D, Principal Invest.
	B. Rydberg	"	Ph.D., Co-Worker
	A. Kronenberg	"	Sc.D., Co-Worker
	D. Chen	"	Ph.D., Co-Worker
	S. Costes	"	Ph.D, Co-Worker
	L. Ding	"	Ph.D., Co-Worker
	P. Yaswen	"	Ph.D., Co-Worker
	K. Andarawewa	"	Ph.D., Co-Worker
	H. Sudo	"	Ph.D., Co-Worker
N-104	**M. Weil**	Colorado State University	Ph.D, Principal Invest.
	M. Callan	"	M.S., Co-Worker
	Y. Peng	"	M.S., Co-Worker
	F. Ray	"	M.S., Co-Worker
N-106	**S. Gatley**	BNL, Medical Dept., Upton, NY	Ph.D, Principal Invest.
	O. Rice	"	Ph.D, Co-Worker
	M. Vazquez	"	M.D, Ph.D, Co-Worker
	S. Saint-Victor	"	B.S., Co-Worker
N-107	**A. Kennedy**	University of Pennsylvania	Ph.D., Principal Invest.
	J. Ware	"	Ph.D., Co-Worker
	X. S. Wan	"	Ph.D., Co-Worker
	J. Guan	"	Ph.D., Co-Worker
	Z. Zhou	"	M.D., Co-Worker
	J. Stewart	"	Ph.D., Co-Worker
	J. Donahue	"	M.S., Co-Worker

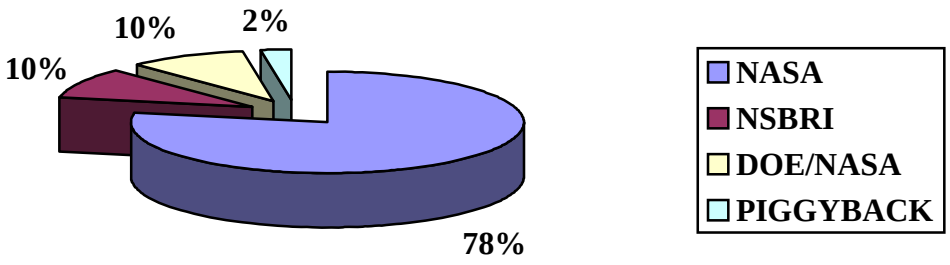
Exp.	Participants	Affiliation	Title
N-110	**G. Nelson ***	Loma Linda University	Ph.D, Principal Invest.
	A. Smith	"	B.S, Co- Worker
	C. Quesada	"	B.S., Co-Worker
	S. Rightnar	"	B.S, Co-Worker
	T. Jones	"	B.S, Co-Worker
	J. Archambeau	"	M.D, Co-Worker
	M. Pecaut	"	Ph.D, Co-Worker
	X. Mao	"	M.D, Co-Worker
	T. Lamp	"	B.S., Co-Worker
N-112	**A. Obenaus**	Loma Linda University	Ph.D, Principal Invest.
N-139	A. Smith	"	B.S, Co-Worker
	C. Quesada	"	B.S., Co-Worker
	T. Lamp	"	B.S., Co-Worker
	M. Robbins	"	B.A., Co-Worker
	S. Chong	"	B.S., Co-Worker
	W. Baqai	"	B.S., Co-Worker
N116	**E. Benton**	ERIL Research Inc., CA	Ph.D, Principal Invest.
	B. Gersey	Praire View A&M University, TX	Ph.D., Co-Worker
	J. Sodolak	"	Student
N-123	**V. Radeka**	BNL, Upton, NY	Ph.D., Principal Invest.
	B. Yu	"	Ph.D, Co-Worker
	J. Mead	"	Ph.D, Co-Worker
N-129	**C. Limoli**	University of California San Francisco	Ph.D., Principal Invest.
	E. Giedzinski	"	Ph.D., Co-Worker
	J. Baure	"	Ph.D., Co-Worker
N-130	**J. Ware***	University of Pennsylvania	Ph.D., Principal Invest.
	A. Kennedy	"	Ph.D., Co-Worker
	J. Guan	"	Ph.D., Co-Worker
	J. Stewart	"	M.D., Co-Worker
	J. Donahue	"	M.S., Co-Worker
N-131	**T. Kohwi-Shigematsu**	LBNL, Berkeley, CA	Ph.D., Principal Invest.
	K. Peet	"	Admin. Assistant
	M. Miyano	"	Ph.D., Co-Worker
	S. Cai	"	Ph.D., Co-Worker
N-132	**S. Amundson**	Columbia University	Ph.D., Principal Invest.
	J. Ahn	"	Staff Associate, Co-Worker
N-133	**E. Azzam**	UMDNJ-New Jersey Medical School	Ph.D., Principal Invest.
N-134	**D. Chen***	University of Texas, Southwestern Medical	Ph.D., Principal Invest.
	M. Story	Center at Dallas	Ph.D., Co-Worker
	S. Burma	"	Ph.D., Co-Worker
	N. Uematsu	University of Texas	Ph.D., Co-Worker
	A. Shivachar	University of Texas	Ph.D., Co-Worker
N-135	**J. Pluth**	LBNL, Berkeley, CA	Ph.D., Principal Invest.
	S. Yannone	"	Ph.D., Co-Worker
N-136	**A. Britt**	University of CA, Davis	Ph.D., Principal Invest.
N-139	**T. Krucker***	Scrip Institute, CA	Ph.D., Principal Invest
N-140	**P. Saganti**	NASA – CARR, Prairie View A&M Univ.	Ph.D., Principal Invest.
	B. Gersey	"	Ph.D., Co-Principal Invest.
	R. Wilkins	"	Ph.D., Co-Principal Invest.
	C. Zeitlin	LBNL, Berkeley, CA	Ph.D., Co-Principal Invest.

***Not Present During Actual Run**

NSRL-5 PARTICIPANTS STATISTICS

PARTICIPANTS	NSRL-5
Ph.D., Principal Investigators	26
M.D., Ph.D., Principal Investigators	1
Ph.D., Co-Principal Investigators	3
B.S., Co-Principal Investigators	1
Co-Workers	
Ph.D.	43
M.D., Ph.D.	1
ScD.	1
M.D.	3
M.S.	9
B.S.	28
B.A.	1
B.S./B.A.	1
Senior Technician	1
Staff Associate	1
Students	2
Administrative Assistant	1
Total:	123

RESEARCH PROJECT SPONSORS:



PARTICIPANT INSTITUTIONS

NASA related centers/institutes (2)

- **NASA, Johnson Space Center, TX**
- **National Space Biomedical Research Institute, TX**

National Laboratories/Institutes (3)

- **Brookhaven National Laboratory, NY**
- **Lawrence Berkeley National Laboratory, CA**
- **HNRCA, USDA-ARS, MA**

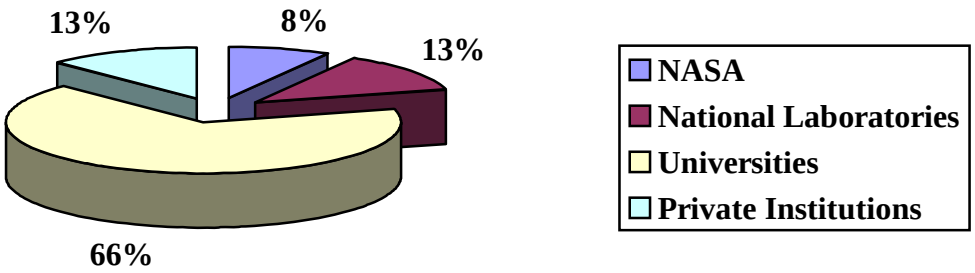
Universities (16)

- **Loma Linda University, CA**
- **University of Pennsylvania, PA**
- **Thomas Jefferson University, PA**
- **Colorado State University, CO**
- **Columbia University, NY**
- **University of Maryland, Baltimore County, MD**
- **Prairie View A&M University, TX**
- **Texas A&M University, TX**
- **Harvard Medical School, MA**
- **UMDNJ-New Jersey Medical School, NJ**
- **New York University, School of Medicine, NY**
- **University of California, San Francisco, CA**
- **University of California, Davis, CA**
- **University of Texas, Southwestern Medical Center of Dallas, TX**
- **AMU, College Station, TX**
- **Oregon Health and Science University, OR**

Private Institutions (3)

- **ERIL Research Inc., CA**
- **Scripps Research Institute, CA**
- **SRI International, CA**

INSTITUTIONS STATISTICS:

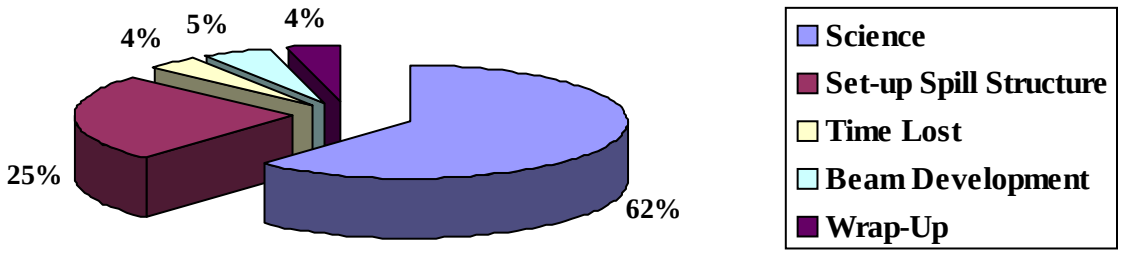


RUN TIME DESCRIPTION (hours)

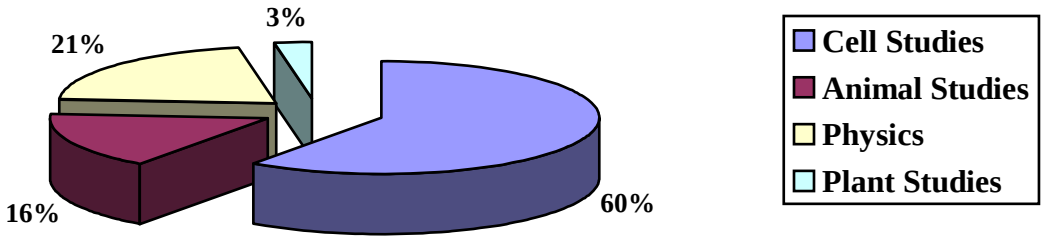
NSRL-5	ION SPECIES AND ENERGIES (MeV/n)								
	Si 600	Fe 1000	Fe 600	H 1000	Fe-H 1000	O 1000	O 600	C 290	Totals
Set-Up-Spill S.	10	33	9	17	3	9	4	9.5	94.5
Wrap-Up	0.5	5.5	2.5	1.5	1	1	0.5	1.5	14
Non-Science Sub-Total: 108.5									
B. Develop.	0	2.5	9	4.5	0	2.5	1.5	0	23
Time lost	0	1.5	4.5	1.5	3.5	0	1	2.5	14.5
Biology									
• In Vitro	0	64	18	14	19.5	1.5	6.5	11.5	135
• In Vivo	2	18	15.5	0	0	3	0	0	38.5
• Others	0	3	0	3	0	0	0	0	6
Physics	4.5	18	4	7.5	0	13.5	0	5	52.5
Science Sub Total: 229.5									
Totals	17	145.5	62.5	49	27	30.5	13.5	30	375

DESCRIPTIVE STATISTICS

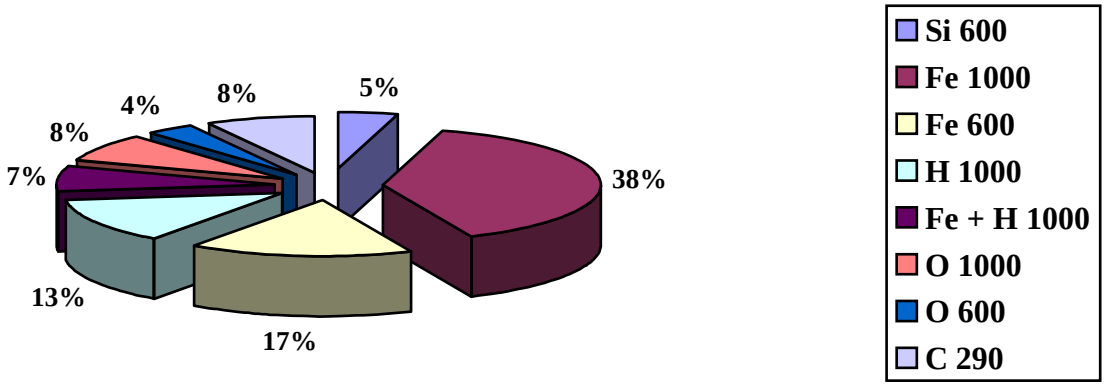
Total NSRL-5 Stats:



Science Studies Stats:



NSRL-5 Ion Species and Energy (MeV/n) Distribution



RUN DATES

	Scheduled		Actual	
H 1000 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**03/28**	**0700**	**03/28**	**0700**
End	**03/28**	**2000**	**03/28**	**2000**
R 2 Start	**04/26**	**0700**	**04/26**	**0700**
End	**04/28**	**1800**	**04/28**	**1230**

Fe 1000 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**03/28**	**2000**	**03/28**	**2000**
End	**03/29**	**2100**	**03/29**	**2200**
R 2 Start	**04/11**	**0700**	**04/11**	**0700**
End	**04/15**	**1900**	**04/15**	**1730**
R 3 Start	**04/18**	**0700**	**04/18**	**0700**
End	**04/25**	**1800**	**04/25**	**1630**

O 1000 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**03/29**	**2300**	**03/30**	**0000**
End	**03/31**	**1800**	**03/31**	**1630**

O 600 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**04/01**	**0700**	**04/01**	**0700**
End	**04/02**	**1100**	**04/01**	**2030**

Fe 600 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**04/04**	**0700**	**04/04**	**0700**
End	**04/09**	**1500**	**04/08**	**2100**

Fe + H 1000 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**04/16**	**0700**	**04/16**	**0700**
End	**04/17**	**2200**	**04/17**	**2230**

C 290 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**04/29**	**0700**	**04/29**	**0700**
End	**05/03**	**1900**	**05/03**	**1800**

Si 600 MeV/n	**Date**	**Time**	**Date**	**Time**
R 1 Start	**05/04**	**0700**	**05/04**	**0700**
End	**05/05**	**1800**	**05/05**	**1930**

NSRL-5 BEAM CHARACTERISTICS

Ion	Fe			H	O		C	Si	
Planned Energy (MeV/n)	**300**	**600**	**1000**	**1000**	**600**	**1000**	**290**	**300**	**600**
Fluence (particles/cm^2/sec)									
Maximum on target	**3.0e6**	**3.0e6**	**3.0e6**	**2.1e8**	**5.5e6**	**5.5e6**	**1.4e7**	**4.5e6**	**4.5e6**
Minimum on target	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Spill Period (sec)	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Spill rate (spills/min)	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Spill length (msec)	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**
Particles/spill									
Maximum	**1.0e9**	**1.0e9**	**1.0e9**	**9.0e10**	**1.9e9**	**1.9e9**	**3.0e9**	**1.6e9**	**1.6e9**
Minimum	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**	**1.0e5**
Beam Cut Off Accuracy	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**
Actual Energy (MeV/n)									
Extracted	**315**	**600**	**1005**	**1000**	**600**	**1000**	**300**	**300**	**600**
On Target	**307.7**	**577**	**969.1**	**1000***	**600***	**1000***	**293.6**	**279.3**	**581.6**
Actual LET on Target (keV/µm)	**235.5**	**176.1**	**151.4**	**0.222***	**16.4***	**14.2***	**12.88**	**72.1**	**50.9**
Max. Dose Rate (Gy/min)/ Beam Size (cm x cm)									
20 x 20	**6.2**	**4.6**	**4.0**	**0.6**	**0.8**	**0.7**	**1.0**	**3.0**	**2.2**
Total Dose (Gy)									
Maximum	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
Minimum	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**

NSRL operations comments:

During this run we commissioned the Digital Beam Imager (DBI), and tested its performance against that of x-ray film. We very quickly started relying on the DBI for beam tuning and exposure monitoring, making little use of the x-ray film. We also commissioned the pixel ion chamber with gain, allowing beam imaging at extremely low rates. Fe 300 MeV/n was developed during this run.

New equipment was added to the target room, including a long-travel, remotely operated exposure translation stage, used primarily by physics during this run. The new Data Acquisition (DAQ) system was commissioned and several tests were performed. NSRL-5 was run behind RHIC polarized protons, making the pulse by pulse modulation (PPM) mode easy. The spill repetition rate, however, was determined by the PPM mode and was once every 5 seconds.

NSRL-5 EXPERIMENTERS AND RUN STATISTICS

Exp. ID	Principal Investigator	Ion & Energy	Beam Time Approved (hours)	Beam Time Used (hours)	Dose Range (cGy)	Dose/Rate (cGy/min)	Number of Samples
B3	Cucinotta	Fe, 0.6 GeV/n	3.0	3.0	10-300	50	40
		O, 0.6GeV/n	3.0	3.0	10-300	50	40
		P, 1GeV/n	4.0	3.0	20-120	50	10
B7	Rabin	Fe, 1GeV/n	3.5	2.25	150	100	16
		Si, 0.6GeV/n	5.0	5.0	10-200	50-100	55
B10	Chang	O, 1GeV/n	4.0	3.5	10-300	20-100	84
		Si, 0.6GeV/n	4.0	2.0	"	"	NA
B52	Gerwitz	C, 0.290GeV/n	3.4	1.0	NA	NA	NA
		P+Fe, 1GeV/n	8.5	8.5	"	"	"
		Si, 1GeV/n	3.5	WT	-	-	-
N65	Vazquez	Fe, 1GeV/n	3.0	2.5	10-100	30-50	20
		Fe, 0.6GeV/n	2.0	2.0	25-200	10-48	28
		O, 1GeV/n	2.0	1.0	2.5-80	1-38	4
B67	Blakely	Fe, 0.6GeV/n	10	11	10-400	20-200	240
B73	Sutherland	Fe, 1GeV/n	2.0	4.0	NA	NA	NA
		Fe, 0.6GeV/n	1.5	2.0	"	"	"
		C, 0.290GeV/n	1.0	1.5	"	"	"
		Si, 1GeV/n	1.0	WT	-	-	-
		P, 1GeV/n	3.0	3.0	"	"	"
B74	Chatterjee / Bedford	Fe, 0.6GeV/n	2.0	1.75	100-300	40-95	30
		O, 1GeV/n	2.0	1.25	"	25-40	NA
		O, 0.6GeV/n	2.0	1.75	"	15-55	NA
B75	Ford	Fe, 1GeV/n	4.0	4.0	0-100	10	37
		P, 1GeV/n	4.0	0	-	-	-
B76	Green	C, 0.290GeV/n	2.0	1.2	10	50	5
N80	Gonda	Fe, 1GeV.n	5.0	3.5	10-200	3-83	48
N86	Wang	Fe, 1GeV/n	4.5	3.5	100-250	100-200	124
N88	Sutherland	C, 0.290GeV/n	1.6	NA	NA	NA	NA
		Si, 0.6GeV/n	1.5	WT	-	-	-
		P+Fe, 1GeV/n	7.0	7.0	NA	NA	NA
N89	Held	Fe, 1GeV/n	6.4	7.75	5-500	5-200	53
		C, 0.290GeV/n	6.3	7.0	"	"	52
		P, 1GeV/n	6.3	7.5	"	"	41
N90	Bailey	Fe, 1GeV/n	2.0	1.0	100-200	100	16
N91	Rydberg	Fe, 1GeV/n	4.0	3.0	5-100	10-100	80
		Fe, 0.6GeV/n	4.0	3.5	"	"	80
N96	Nelson	Fe, 0.6GeV/n	4.0	3.0	50-5000	200	6
N97	Kronenberg	Fe, 1GeV/n	10	6.45	0-200	50-100	110
N99	Zhao	Fe, 0.6GeV/n	0.5	0.25	60-100	50	18
N102	Hall	Fe, 1GeV/n	2.5	2.167	10-300	10-75	48
N103	Barcellos-Hoff	Fe, 1GeV/n	9.7	7.0	10-500	20, 100	80
N104	Weil/ Ulrich	Fe, 1GeV/n	9.0	7.0	10-100	10-40	370
N106	Gatley	Fe, 0.6GeV/n	4.0	4.0	120-240	100-200	40

Exp. ID	Principal Investigator	Ion & Energy	Beam Time Approved (hours)	Beam Time Used (hours)	Dose Range (cGy)	Dose/Rate (cGy/min)	Number of Samples
N107	Kennedy	Fe, 1GeV/n C, 0.290GeV/n	6.5 3.5	3.0 WT	10-20 -	10-20 -	144 -
N110	Nelson	Fe, 0.6GeV/n	3.7	2.0	NA	NA	NA
N112	Obenaus	Fe, 0.6GeV/n	3.5	4.0	50-400	200	24
N116	Benton	Fe, 1GeV/n O, 1GeV/n P, 1GeV/n	12.0 12.0 6.0	12.0 12.0 7.5	NA “	NA “ “	NA “ “
N123	Radeka	Fe, 1GeV/n O, 1GeV/n	7.0 3.0	6.0 WT	NA	NA	NA
N129	Limoli	Fe, 1GeV/n	4.0	4.0	10-500	25-100	100
N130	Ware	Fe, 1GeV/n P, 1GeV/n	1.5 3.5	NA WT	NA -	NA -	NA -
N131	Kohwi-Shigematsu	Fe, 1GeV/n	2.0	1.0	5-150	5-50	12
N132	Amundson	Fe, 1GeV/n	2.0	1.0	10-250	20, 50	16
N134	Chen	Fe, 1GeV/n	2.0	2.0	0.1-100	3-50	28
N135	Pluth	Fe, 1GeV/n	8.0	6.0	5-600	0.1-200	68
N136	Britt	P+Fe, 1GeV/n	2.5	3.0	500-20000	350	96
N137	Wilkins	Fe, 0.6GeV/n	15.0	WT	-	-	-
N139(108)	Krucker	Fe, 0.6GeV/n	4.3	2.0	0-400	200	20
N140	Saganti	Fe, 0.6GeV/n C, 0.290GeV/n Si, 0.6GeV/n	2.25 2.25 2.25	4.0 5.0 4.0	NA “ “	NA “ “	NA “ “
N141(113)	Krucker	Fe, 0.6GeV/n	2.6	2.0	NA	NA	NA
N142	Burns	Fe, 1GeV/n	7.0	7.0	150-300	200	16
Totals			**290**	**229.5**	**10 - 20000**	**0.1- 350**	**2000+**

NSRL-5 PARTICIPANTS, EXPERIMENTAL SAMPLES AND ENDPOINTS

Exp.	Participants	Samples	Endpoints
B-3	Heavy Ion Induced Chromosome Damage and Biomedical Countermeasures **F. Cucinotta (PI)**	Human Lymphocytes, Human Fibroblasts, and Chinese Hamster cells	Chromosome damage, structure effects on DNA double strand break induction and repair.
B-7	Effects of Exposure to Heavy Particles **B. Rabin (PI)**	Sprague Dawley Rats	Behavioral paradigms and neurochemistry
B-10	Charged Particle Radiation-induced Genetic Damage in Transgenic Mice **P. Chang (PI)**	LacZ transgenic mouse with different p53 genotypes	Mutation frequency, micronucleus formation and chromosomal aberrations
B-52	Effect of Deep Space radiation on Human Hematopoietic Stem Cells. **A. Gewirtz (PI)**	Human bone marrow cells	DNA complex damages, DNA replication and apoptosis, gene expression
N-65	Risk Assessment and Chemoprevention of HZE-Induced CNS Damage. **M. Vazquez (PI)**	NT2 human neural stem cells and hNT neurons.	Survival, apoptosis, gene expression.
B-67	Lens Epithelium and Proton-Induced Cataractogenesis. **E. Blakely (PI)**	Human lens epithelial cells	RNA or protein analyses
B-73	DNA damage clusters in low level radiation responses of human cells. **B. Sutherland (PI)**	T7 DNA, Human monocytes Supercoiled DNA	DNA damage cluster induction and repair at the molecular and cellular levels
B-74	Chromosomal Damage Measurements **A. Chatterjee (PI)**	Human fibroblasts	Chromosomal aberrations and shielding.
B-75	Low dose response of respiratory cells in intact tissue and reconstituted constructs **J. Ford (PI)**	Rodent tracheal tissue	Immunohistochemistry of repair proteins and apoptosis. Track structure.
B-76	Response of Thyroid Tissue Units to Space-Like Radiation Fields. **Lora Green (PI)**	FRTL-5 cells (rat thyroid)	RNA gene arrays, Analysis of fixed tissue/cells for specific quantification of structural components
N-86	Cellular Response to High Energy Particle Exposures. **Y. Wang (PI)**	GM 847 and ATR-kd human fibroblasts	Clonogenic survival, G2 checkpoint, DNA replication, CHK1 phosphorylation and DNA repair.
N-88	Complex Space Radiation-induced DNA damage Clusters in Human Cell Transformation: Mechanisms, relationships and Mitigation. **B. Sutherland (PI)**	Human normal fibroblasts	DNA damage cluster and transformation
N-89	Induction of Bystander Effects by High LET Radiation in Cells **K. Held (PI)**	Human keratinocytes and fibroblasts	Micronuclei formation, expression of p21 and foci formation of γH2AX

Exp.	Participants	Samples	Endpoints
N-90	Genetic effects of siRNA knockdown of non-homologous end joining proteins_in human lymphoblast cells **S. Bailey (PI)**	TK6 human lymphoblast cell.	Chromosome aberration formation, mutagenesis and telomere fusions.
N-91	Repair of HZE-induced DNA Double Strand Breaks and PCC Breaks. **B. Rydberg (PI)**	HeLa cells, CHO cells and xrs6 cells	DSB determination, PCC and bystander effects
N-96	Gene Expression in the Nematode C. elegans following Irradiation with Charged Particles **G. Nelson (PI)**	Nematode C. elegans	Gene expression. Microarrays.
N-97	Comparative analysis of Fe ion-induced mutations in murine tissue and cell lines. **A. Kronenberg (PI**	Human kidney cells *Aprt*+/- mouse kidney cells Mice	Mutation frequency, Cell toxicity, apoptosis
N-99	Tranformation of hTERT-immortalized human bronchial epithelial Cells by High Energy Heavy Ions. **Y. Zhao (PI)**	hTERT-immortalized human bronchial epithelial Cells and MEF cells	Cell survival and transformation
N-102	Exposure of Mouse Cells to Graded Doses of One GeV/nucleon Fe(56) Ions. **E. Hall (PI)**	Thymocytes from wild type knock out mice	Apoptosis assays
N-103	Mechanism of HZE Damage and Repair in Human Epithelial Cells. **M. Barcellos-Hoff (PI)**	HMEC 184	Survival assays, Gene expression, Immunostaining
N-104	Radiation Leukemogenesis **M. Weil/R. Ullrich (PI's)**	CBA/CaJ strain mice	Determination of RBE for the induction of AML using slope constants
N-106	MicroPET Studies of Brain Damage by Heavy Ion Particles. **S. Gatley (PI)**	Rats	Neurochemical analysis, MicroPET imaging
N-107	Effects of L-Selenomethionine and other Agents on HZE Particle Radiation Induced Cell Killing and Malignant Transformation in vitro. **A. Kennedy (PI)**	Htori-3 cells (Human Thyroid Epithelial Cells)	Radioprotective effects of L-selenomethionine (SeM), immunofluorescence assays, colony formation
N-110	Charged Particle Irradiation Causes a Progressive Loss of Cells and a Remodeling of CNS Tissue as a Function of Dose, Time, and LET. **G. Nelson (PI)**	C57BL/6 Mice	Immunohistochemical analysis, stereology *in situ*, immunocytochemistry
N-112	Charged Particle Alterations of the Functional Output of the Brain as a Function of Dose, Time, and LET	C57BL/6	EEG Recordings, In Vitro brain slice preparation, Extracellular recordings and Long Term Potentiation, Quantitative estimates of venous CBV

Exp.	Participants	Samples	Endpoints
	A. Obenaus (PI)		
N-116	Benchmark Analysis and Evaluations of Materials for Shielding/Radiation Shielding Properties of Multifunctional Spacecraft. **E. Benton (PI)**	Assorted Target Shielding Materials	Beam measurements using TEPC, CR-39 PNTDs, and Liulin MDU
N-123	Heavy Ion Microbeam and Micron Resolution Detector for Single Cell Radiation Studies. **V. Radeka (PI)**	Stripixel Detector	Position resolution and linearity in position response
N-129	Effects of Heavy Ions on Neural Precursor Cells **C. Limoli (PI)**	Mice Primary precursor cell culture. Mice	ROS production. Apoptosis
N-130	Screening single antioxidant agents as protectors against space-radiation-induced malignant transformation **J. Ware (PI)**	HTori-3 cells	Cytotoxicity and malignant transformation
N-131	Effects of ^{56}Fe-Particle Radiation on Thymocytes from SATB1-null Mice **Kohwi-Shigematsu (PI)**	Thymocytes from SATB1-null Mice	
N-132	Functional Genomic responses to HZE particles **S. Amundson (PI)**	p53-wild-type TK6 cell, p53-null NH32 cell line	Gene expression, colony formation, FACS.
N-133	Mitochondrial Response to Low Fluences of High Energy Charged Particles **E. Azzam (PI)**	human fibroblasts	Mitochondrial function. i) protein import, ii) protein synthesis, iii) oxidative damage and v) morphology.
N-134	DNA damage responses induced by HZE particles in human cells. **D. Chen (PI)**	Human skin fibroblasts (HSF42)	Cytotoxicity, DNA damage (H2AX), gene expression, bystander effect.
N-135	Protein Phosphorylation Profiles After HZE Exposure **J. Pluth (PI)**	Fibroblast and lymphocytes	BrdU incorporation FACS based survival assay and colony formation assays
N-136	IR-induced damage response and repair requirements in Arabidopsis **A. Britt (PI)**	Arabidopsis	Growth-responses and formation of H2AX foci, somatic loss of heterozygosity
N-139	The effects of charged particle radiation on neurodeg. disease progression. **T. Krucker (PI)**	APP23 transgenic mice	Vascular alterations and histopathology
N-140	Heavy Ion Particle Impact on the Mars Surface and the Measurement of Secondary Particle Flux: Assessment with the Martian Regolith. **P. Saganti (PI)**	Martian regolith targets with simulated Martian	Neutron production flux measurements

List of personnel that participated in the planning, organization and execution of NSRL-5 run

BNL Management:

- Laboratory Director: **Praveen Chaudhari**
- Associate Director for High Energy and Nuclear Physics**: Tom Kirk**
- Associate Laboratory Director for Life Sciences: **Helene Benveniste**

NASA Management:

- Headquarters: **Walter Schimmerling, David Tomko**
- JSC: **Frank Cucinotta, Frank Sulzman, Barbara Corbin**

Scientific Advisory Committee:

- **Betsy Sutherland** (Chair), BNL
- **Louis Pena,** BNL
- **Richard Setlow,** BNL
- **Kathy Held,** MIT
- **Les Braby,** PNL
- **Charles Geard,** Columbia University
- **John Gatley,** BNL

Collider Accelerator Department-AGS

- Chairman: **Derek Lowenstein**
- Deputy Chairman: **W.T. Weng**
- Associate Chair of Operations: **A.J. McNerney**
- Experimental Planning and Support Head: **Philip Pile**
- Associate Chair for ESHQ: **Ed Lessard**
- ESHQ Division Head: **Ray Karol**
- ESH Coordinator: **Asher Etkin**
- Facility Support Representative: **Chuck Schaefer / Henry Kahnhauser**
- Environmental Coordinator: **Joel Scott**
- Training and Procedures Manager : **John Maraviglia**
- Main Control Room: **Peter Ingrassia**
- Work Control Manager: **Peter Cirnigliaro**
- BNL Laser Safety Officer: **Chris Weilandics**
- Experimental Safety Review Committee: **Yousef Makdisi (Chair)**
- Radiation Safety Committee: **Dana Beavis (Chair)**
- **Acc**elerator Safety Review Committee: **Woody Glenn (Chair)**

- ALARA Committee: **Chuck Schaefer (Chair**
- Associate Chair for ES&H/Q.A: **E. Lessard**
- Accelerator Division Head: **Thomas Roser**
- Chief Electrical Engineer: **J. Sandberg**
- Chief Mechanical Engineer: **J. Tuozzolo**
- Accelerator Physicist lead by: **Leif Aherns**
- Tanden Group leader: **Peter Thieberger**
- Physics Support: **Yusef Makadisi**
- CAD Components and instrumentation support: **David Gassner**
- AGS Radiation Safety Committee: **Ken Reece**
- C-A Dept Training Manager: **John Maraviglia**
- AGS Control Section lead by: **Don Barton**
- Liaison Engineering Group lead by: **David Phillips**
- Liaison physicist: **Adam Rusek**
- RHIC&AGS Users Center: **Susan White-DePace, Angela Melocoton**
- Mechanical Service Technicians led by: **Fred Kobasiuk**
- Survey Group led by: **Frank Karl**
- Beam Service Technicians led by**: Paul Valli**
- Electronic Service Technicians led by: **Bill Anderson**
- AGS Instrumentation Group led by: **Pete Stillman**
- AGS Main Control Room and Operations led by: **Pete Ingrassia**
- **AGS MCR Operation Coordinators:**

  Jim Jamilkowski
  Sanjee Abeytunge
  Jennifer Kozak
  Brian van Kuik,
  Travis Shrey
- AGS Electricians led by **Bill Softye**
- AGS Riggers led by: **Nick Cipolla**
- Carpenter and Welder Support Service and Technical Support led by: **Roger Hubbard**

Dosimetry:

- **Adam Rusek**
- **I-Hung Chiang**
- **Kin Yip**
- **Peter Oddo**

- **Bart Frak**

Medical Department:

NASA LTSF TEAM:

- **Medical Liaisons: Marcelo E. Vazquez, Peter Guida**
- **Technical support: Bea Pyatt, Adele Billups, Laura Thompson**
- **Secretarial support: Fran Capasso**

- Dept. Chair: **Helene Benveniste**
- Building Manager: **Chris Harris**
- Administration: **Denise White and Donna Russo**
- Animal Care Facilities: **Maryann Kershaw, Kerry Bonti, Patricia Leone**
- Training Coordinator: **Ann Emrick**
- **RCD**
    - Kay Conkling
    - Dennis Ryan
    - Deana Buckallew
    - Jim Williams
    - Bob Colichio

Plant Engineering:

- BLAF Custodian, **P. Abrams**
- Plumbers: **B. McCafferty**
- Painters/Carpenters: **B. Laakmann**
- Electricians: **T. Baldwin**

Biology Department:

- Chairman: **Carl Anderson**
- Biology Liason: **Betsy Sutherland**
- Technical Support: **Mamta Naidu, Debasish Roy, Stefan Tafrov**
- Cesiun Source Manager: **Richard Sautkulis**